AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

No. 809.

THE FINANCIAL MANAGEMENT OF WATER-WORKS.

By E. KUICHLING, M. Am. Soc. C. E.

PRESENTED MAY 19TH, 1897.

WITH DISCUSSION.

The questions involved in the financial management of a municipal water-works system are often very interesting, even though they may be somewhat complicated, and it is doubtless owing to the difficulties encountered in the analysis of the problem that no generally accepted principles of such management have yet been formulated. Various methods of procedure have been adopted in different places, but rarely has it happened that any one of them received general approbation or was adopted elsewhere without more or less modification. In most places the exercise of sound judgment is hampered by considerations of expediency, and hence temporary or superficial plans of financial management are in vogue which must sooner or later be materially amended.

Much confusion is also caused by the careless use of terms in the discussion of the subject, as well as in the classification of the various items of income or expense. That which is treated as a maintenance or repair account in one city will often be charged to construction in

another place, and in some cases the cost will be divided arbitrarily between the two accounts. Again, a distinction is sometimes made between the maintenance and the repair accounts, and when renewals or improvements of any part of the works are made, a separate account may be opened. It is therefore necessary to examine the financial statements relating to the water-works of different cities with the utmost care in order to avoid serious error in making comparisons.

These facts, along with the scarcity of well-digested literature on the subject, were forcibly brought home to the author in the course of an extended investigation of the financial features of the municipal water-works with which he is connected. The inquiry was made by a committee from another branch of the city's government, and the questions which arose seemed at first easy of solution. Upon further reflection, however, the strict equities in the case did not appear so simple, and precedents for conflicting opinions were eagerly sought in the experience of other large communities. A large number of municipal reports, technical journals and society transactions were consulted in the hope of finding therein some clearly defined general principles of financial management for costly public works, but, unfortunately, those which were available at the time contained few useful references to the matter and no extensive discussions. It, therefore, devolved upon the author to formulate his own views in the premises, and the greater part of the following paper was prepared before the appearance of the valuable article * on the same subject by Freeman C. Coffin, M. Am. Soc. C. E.

This explanation and early reference to Mr. Coffin's work is made both on account of the similarity of the arguments in the two papers and to avert the charge of wholesale plagiarism on the author's part. It is also proper to state that in preparing the present paper, the author has in some instances availed himself of Mr. Coffin's expressions, for which due acknowledgment is herewith made; and although the subject is now no longer new, yet it is believed that the further discussion of sound administrative policy in the management of expensive public water-works cannot fail to be of interest to the engineering profession in general. The paper is accordingly submitted with the hope that it will elicit some account of the financial conditions and policies which prevail in other municipal water departments, so that when similar

* See the *Journal* of the New England Water-Works Association for September, 1896.

investigations are made hereafter, a useful fund of pertinent information may be at hand.

Expenses.—In dealing with the annual expenses or charges against a water-works system, the following items are to be taken into consideration:

I. The interest on the bonded debt incurred for construction.

II. A yearly payment into a sinking fund for the ultimate liquidation of the bonded debt.

III. A yearly payment into a fund for the periodical renewal of the perishable parts of the works.

IV. The yearly operating expenses, including ordinary repairs and minor betterments.

V. The average cost of the usual yearly extensions or improvements of the distributing system.

VI. A yearly contribution to a fund for the payment of anticipated future extensions of, or additions to, the supply system.

VII. The interest on all capital expended for construction over and above the bonded debt.

VIII. A profit on the investment in addition to the preceding items.

In the case of successful private corporations, all of these items are taken into account, directly or indirectly, in fixing the rates charged for the service, goods or product, and it is frequently claimed that the same practice should be followed in the case of municipal water-works. Careful reflection, however, will lead to the conclusion that such a course is generally inexpedient, for the reason that a service undertaken by a community for its own exclusive benefit, and through its own government, is essentially a co-operative or mutual enterprise, the product of which is expected to be sold at cost to the participants; also because it is manifestly absurd to demand that one branch of the municipal service shall yield a profit in order that the work involved in another department may ostensibly be performed for less than its true cost.

Strictly considered, the expenses of each department of a city's government should be tabulated separately, and the proper value of any service rendered, or materials furnished, by one department to another should be duly credited and charged in the respective accounts. By this means alone will the real cost of any department, as

well as the value of any service rendered by it, become known, and whenever it may be deemed expedient to make the revenue of such department large enough to yield a profit or surplus over its legitimate expenses, the fact should be distinctly announced and the reasons therefor intelligently explained. Under ordinary conditions, however, it seldom happens that a community deems it proper to make an appreciable profit from any service rendered to the citizens, and hence this item may at once be eliminated.

It is also very unusual for communities to demand from citizens payment for interest on past cash expenditures for the construction of public works, or to require of them annual contributions for the creation of a fund which is to be expended at some distant future time for building prospective new works. The principles here involved are, on the one hand, that an adequate benefit has been derived from past payments, and on the other hand, that there is no obligation on the present generation to provide for remote future demands. No extended argument in support of these two principles appears to be necessary, it being understood that the future demands mentioned relate to entirely new works instead of to the proper maintenance of the existing ones; and hence the sixth and seventh items in the foregoing list may fairly be omitted.

With reference to the fifth item, which is a provision for the usual yearly extensions and improvements of the system of distributing pipes, in order that the service may keep pace with the ordinary increase of population and development of urban territory, it may strongly be urged that inasmuch as such increase is often quite variable, no definite limit to the annual provision can be assigned, and that the required sums for this purpose shall be fixed each year in proportion to the necessities. By this method the annual extensions of the pipe system will properly come under the head of construction, and be paid for by general taxation, as in the past. It must also be borne in mind that all such extensions are presumed to involve immediate benefits fully commensurate with the outlay, and that the tax on the additional valuation of property ensuing therefrom will ultimately repay the investment. The fifth item may therefore likewise be omitted from the list of charges against the works.

Accordingly only the first four items of expense are left to be met by the revenue derived from the works, viz., the interest on the bonded

debt, the sinking fund provision for the ultimate liquidation of this debt, the depreciation fund provision for the periodical renewal of the perishable parts of the works, and the annual operating expenses.   Of these, the second and third are frequently combined into a single item, and may form a large or small percentage of the total yearly cost, depending upon the proportion of the aggregate amount which is left to posterity to pay.   With regard to the first and fourth items, it is obvious that they should be paid in full by the present inhabitants, and that the financial burden of the next generation should not be increased by any portion of these expenses.

Concerning the provision for sinking and depreciation funds, a considerable diversity of practice is found.   In some cities it has been assumed that the generation which incurred a certain bonded debt for a water-works system should provide for its payment in full, besides leaving an adequate surplus for the renewal of the perishable parts of the system, so that the succeeding generation will inherit the works entirely free from debt and with its perishable parts renewed.   In other places, however, this plan is regarded as much too generous, and provision is made only for maintaining the works in good order, so that posterity shall not have on its hands a worn-out or greatly depreciated plant, in addition to the original debt.   A third plan is for the present generation to provide for the payment of so much of the bonded debt as relates to the perishable parts of the works, leaving the remainder to be taken care of by posterity, and also to provide for the proper maintenance of the plant so as to leave it in good condition.

From the meager data available, it seems that the usual practice in American cities has been to provide only for a general fund which may be used at its maturity, either for renewing a part of the works, or for paying off a portion of the bonded debt, but which is not sufficient for both purposes.   The object has been merely to keep the finances of the works in tolerable equilibrium from time to time, so as to prevent the present generation from imposing undue liabilities upon its successor, but without leaving to it very good assets, or works from which it will derive much benefit except at the expense of more or less reconstruction.   By this plan the works never become free from debt, but if they are maintained in good order, their value may be equal to the bonded liability.   This condition is essential to solvency, and is ac-

cordingly the lowest limit in the financial scale to which the works
should be allowed to fall.

A somewhat safer plan to follow is the third one indicated above,
by which provision is made not only for the renewal of the perishable
parts of the works but also for the extinction of the original cost of
these parts. The plant will thereby be turned over to posterity par-
tially paid for and in good condition, or with the means for putting
it into such condition. To the extent of their capacity the works will
then serve the future as they did the past or present, and it is there-
fore proper that the future should bear at least the cost of the per-
manent portions, as well as the subsequent renewals. The burden is
thus divided between two or more generations, each paying a reason-
able share of the total original cost; and at the same time, some con-
sideration is expressed for the greater expenditures of the future, which
will assuredly come with increase of population and the constant de-
mands for the improvement of the general welfare.

In relation to the life of the perishable parts of a water-works
system, little definite knowledge is yet available. Pipes and their ap-
purtenances may last for from twenty to fifty years, according to cir-
cumstances, while steam boilers and pumping machinery may have to
be renewed more frequently ; but in general it may be assumed that
with the changes rendered necessary in a growing city by the gradual
development of residential into commercial districts, the costs in-
volved in maintaining a proper standard of efficiency for the works are
practically equivalent to a renewal of the perishable parts of the plant
every thirty years. The same period of time has also been generally
adopted as the duration of the sinking fund for liquidating the
bonded debt of the works ; and until better statistics have been
gathered, this limit may be accordingly adopted for the maturity of
both funds.

To exhibit the English practice in regard to the repayment of loans
for the construction of public works, it may be mentioned that out of
223 loans, amounting in the aggregate to nearly $5 000 000, made by
the Local Government Board to various communities in 1874, about
61% of both the number and the amount of money was for a period of
thirty years ; 5.8% of the number and 15.5% of the amount was for
periods from thirty-one to fifty-seven years ; while the remainder of
both number and amount was for periods less than thirty years ; and

similarly in 1892, out of 1 122 loans sanctioned by the same Board to urban and rural sanitary districts, 41.5% was for thirty years, 10.6% for from thirty-one to fifty years, and 47.9% for less than thirty years. Furthermore, out of the 104 loans made in the latter year for a period of fifty years, 89 were specifically mentioned as being for the purchase of land, thus recognizing the principle that the payment of the cost of the permanent parts of public improvements may fairly be transmitted to posterity in some degree.

As the gradual formation of a fund by a series of annual payments is generally understood only in a vague manner outside of financial circles, a few words on this subject may be permitted. Each annual payment is to be invested so as to yield a good rate of interest, which is to be added to the said payment or principal every succeeding year, the interest for such year then being computed on the sum. Compound interest is thus had on each of the annual payments, and the sum of these payments with accrued compound interest constitutes the fund. Expressed in mathematical terms, the annual payment s, which must be made during a period of n years, and will be invested at compound interest at the rate of r % in order to produce a certain ultimate principal or sum p, is found from the equation :

$$s = \frac{r}{(100+r)\left\{\left(1+\frac{r}{100}\right)^n - 1\right\}} p.$$

Assuming $n = 30$ and $r = 3$, $s = 0.02041\ p$; or, in other words, the annual payment s made during a period of thirty years and bearing compound interest at 3%, must be about one-fiftieth or 2% of the ultimate required sum p. In like manner, if compound interest at $3\frac{1}{2}$% could be secured on the annual payments, the amount of each such payment would be 1.872% of the sum p; and if compound interest at 4% were obtained, the annual payments would become 1.715% of this sum. In general, therefore, it may be said that the yearly charge against the works for the production of a fund sufficient to pay off the original cost of the perishable parts, or to renew them after a period of thirty years, should be about 2% of such cost, and if both items are considered, the yearly charge should be 4% of this cost.

The foregoing analysis of the problem thus leads to the conclusion that the proper annual charges or expenses of a municipal water-works system should embrace the interest on the bonded debt for con-

struction, a contribution to a thirty-year sinking and renewal fund for
the perishable parts of the plant alone, and the operating expenses,
including ordinary repairs and betterments. All extensions and
material improvements of the system should be regarded as new con-
struction work, to be paid for by general taxation ; but a certain per-
centage of such cost, sufficient to furnish the amount necessary for
renewal, as aforesaid, should be charged to the works, since it may
fairly be presumed that a corresponding revenue will be derived from
such extensions. On the other hand, the works should not be
charged with interest on past cash payments for extensions, or for a
sinking fund for the same, or for a profit.

Revenue.—Having considered the proper yearly charges or expenses
of a municipal water-works, and knowing that the system should have
a revenue equal in amount to such expenses, it next becomes of im-
portance to ascertain how this revenue should be obtained. Obviously
the entire sum must be paid by the citizens, either by assessment
upon all taxable property, or by assessment upon the real estate
alone which is served, or by direct charge for the quantity of water
actually or presumably used in the premises of each consumer, or by
a combination of these charges. The latter method is commonly
adopted, inasmuch as a considerable percentage of the water is used
for a great variety of general public purposes, and its value should ac-
cordingly be paid by a uniformly distributed charge upon all taxable
property. In addition to this sum, however, a certain proportion of
the total yearly cost should also be paid by general taxation, since a
large share of the expense of construction and maintenance is due to
the necessary enlargement of the capacity of the pipes, reservoirs,
pumping machinery, etc., for the suppression of fires and to provide
for the future growth of the community.

In regard to the proportion of the total yearly cost which should
be paid by general taxation on account of the initial enlargement of
the works for fire, public and future purposes, much diversity of
opinion exists. Some contend that this charge should be borne entirely
by the present consumers, while others claim that it should be paid
by assessment upon all taxable property, in order to make the water
rates as low as possible. By the latter class of advocates a sharp dis-
tinction is made between taxpayers and water consumers, or, as it may
otherwise be expressed, between the taxable property of a community

and the individuals, corporations or civic departments which consume
the water; and they insist that inasmuch as the annual cost was
incurred for the general public benefit, instead of for individuals, all
taxable property should be assessed therefor uniformly, exactly as in
the case of the public school, fire and police services. This argument
is a very strong one, and appears to have been generally recognized
in one form or another, such as the payment of a rental for fire
hydrants to private water supply companies, or the payment of a por-
tion of the yearly interest account where the works are owned by the
community. It may therefore be assumed that public opinion is gen-
erally in favor of the proposition that some part of the yearly cost of
the works should be paid by uniform assessment upon all taxable
property.

It is obvious that the provision for adequate fire protection and
future growth of the community materially increases the cost of con-
struction over that which would be required to furnish only the quan-
tity of water needed for domestic and manufacturing purposes. While
the aggregate amount of water used per year for suppressing fires
may be but a small percentage of the total supply, yet it must be
delivered in large volume during short periods of time and without
causing appreciable interference with all other uses. As a consequence,
nearly every part of the works must have considerably greater capacity
than is required for the service of individual consumers alone; and the
same is manifestly true when provision is made for future growth. A
number of estimates of the increased cost of construction to afford fire
protection alone have been made by several experienced engineers,
from which it appears that such increase is at least 60%, or that over
one-third of the entire cost is expended for meeting this requirement;
and it may also be added that a recent analysis of the cost of the works
with which the author is connected has led to practically the same
conclusion.

With reference to the provision for future growth of the commu-
nity, the proportional costs of construction vary from year to year, as
the expectations of increase are being realized. Ordinarily, the main
features of the water-works of a large city are designed so as to require
no enlargement for a period of from twenty to forty years, during
which time the population will probably be doubled. The cost of this
provision may, in general, be taken at fully 30% of the total original

expense, or about the same as for the fire protection; and as it was incurred essentially with the purpose of attracting other people to become permanent residents of the city and increase its wealth, the investment partakes of the nature of public speculation. In this view of the case, it is proper that the yearly cost of such investment should be borne, in part, at least, by the entire taxable property. By the increase of population, however, the yearly consumption of water gradually becomes larger, and if the price is based on the quantity used, the annual contribution to the necessary revenue from general taxation will gradually diminish, and will cease entirely in this respect after the original provision for future growth is exhausted.

In opposition to this method of securing a portion of the revenue, it may be urged that the entire yearly cost of the said provision should be included in the water rents, on the ground that the taxable property of the community is sufficiently burdened with the other charges previously mentioned. If this plan were adopted, the rates for the use of the water would necessarily be very high at the outset, but might be reduced from year to year as the consumption increases. Such a policy is, however, generally regarded as unwise in commercial circles, since great stress is laid upon low and unfluctuating water rates, whereby a strong inducement is offered to the establishment of new industrial enterprises, which will cause a far more rapid increase of the wealth of the city than can possibly ensue from the slower growth of the residential population alone. When it is argued in such circles that a somewhat higher general tax rate must make up the deficiency in revenue which results from a low price for the water, the answer is promptly given that a moderate addition to the general taxes is so widely distributed as to be practically inappreciable to the great majority of taxpayers, and that the increase in the value of real estate, due to the presence of such industries in the community, abundantly compensates the owners thereof for their slightly higher taxation; whereas, if the same amount were to be added in the water rents, the burden would fall heavily upon the proprietors of industrial establishments, on whose enterprise the prosperity of the public is principally dependent.

There is, however, another excellent reason for making a division of the financial burden between persons and property which is not often considered. This is the average annual saving in the amount of

fire insurance premiums paid by the property-owners, after the intro-
duction of an efficient system of water-works, over that which would
be required if the city had no public water supply, and as the loss by
fires is never fully compensated by the insurance, there is also the aver-
age annual saving in such uncompensated loss to the community in
consequence of the operation of the water-works. Even a very super-
ficial investigation of the statistics relating to insurance and fire losses
in large cities brings to light the fact that these two savings are of
great magnitude, and a close analysis demonstrates that they are often
larger than the annual interest charges on the entire cost of the works.
Manifestly the benefit thus gained applies mainly to property, al-
though some advantage also results to persons by reason of the greater
chance for continuous employment in a city where fires are quickly
suppressed.

These considerations also lead to the further fact that the require-
ments of modern civilization render the development of a large city
and the resulting great increase in the value of real estate impossible
without an adequate system of water supply or fire protection. In
nearly all cases, the appreciation in the value of such property soon
after the introduction of water-works becomes much larger than the
cost of the plant, and its market price continues to advance steadily
with the subsequent growth of population. This rise in value and
the reduction in rates of insurance and fire loss are clearly benefits
which accrue only to property, as opposed to persons or water con-
sumers, and it therefore follows that an equitable division of the
yearly charges should be made between these two elements.

While much more might be said upon the question, it seems to be
generally conceded that the water rates of a large city should be as
low as possible, and that a considerable proportion of the annual ex-
penses of the works should be paid by general taxation. From the fore-
going it has been shown that, on an average, fully one-third of the yearly
interest on the bonded debt for a public water supply is incurred for
fire protection, and about the same amount for the provision for future
growth. The whole of the former and perhaps about one-half of the
latter should fairly be paid by general taxation, and in addition
thereto compensation should also be allowed at the established rates for
the water which is used for general public purposes; the remainder of
the revenue required to pay the annual expenses may then be obtained

by charges for the use of the water by all classes of private consumers. Under such conditions, and with the understanding that the interest account includes an adequate sum for sinking fund and depreciation, the works may be regarded as conducted on proper business principles, without discrimination in favor of either taxpayer or consumer.

Application to a Particular Case.—The foregoing principles will now be applied to the case of an inland manufacturing city of 100 000 inhabitants, using on the average 8 000 000 galls. of water per day, and having a gravity conduit with a capacity of 14 000 000 galls. per day, costing $600 000; a distributing reservoir of 40 000 000 galls. capacity, costing $150 000; an efficient distributing system of 150 miles of pipe, ranging from 4 to 24 ins. in diameter, costing $1 600 000; and costs of administration, land, damages, etc., during construction of $650 000; thus making a total original cost of $3 000 000, all of which is a bonded debt bearing 5% interest. It will further be assumed that the cost of the perishable parts of the plant is $800 000; that the probable life of these parts is thirty years, and that this amount of the total debt is not only to be extinguished by an annual payment into a sinking fund, but is also to be on hand for renewing such parts at the end of the time named; also that the yearly operating expenses, including minor repairs, are $50 000.

As was pointed out previously, the annual contribution to a thirty-year sinking fund is about 2% of the amount which is to be accumulated; and since in this case both a sinking and a renewal fund, each in the sum of $800 000, are to be provided, the yearly charges therefor will accordingly be 4% of this amount, or $32 000. Adding the interest on the bonds and the operating expenses, as aforesaid, the total yearly expense account will thus be $232 000. The question now arises as to the proportion of this sum which should be borne by general taxation, it being assumed that the water is to be supplied to consumers without profit, and that the continued prosperity of the community depends upon an equitable division of the annual expense between taxpayers and water consumers.

From the given conditions, it may readily be taken for granted, without further analysis, that fully one-third of the bonded debt was here incurred for fire protection, and another third in allowing for the future growth of the city. The interest on the former sum and about one-half of that on the latter should properly be paid by general

taxation, the amount thus raised being $75 000.   To this should also be added some proportion of the annual operating expenses, since the costs of maintenance are manifestly greater with pipes of large diameter than with small ones, and much expense is involved in the care of fire hydrants in winter.   A reasonable estimate of such proportion is about one-fifth, so that $10 000 more would be obtained by general tax on this account.   Furthermore, the water which is used for various public purposes, such as sprinkling and cleaning streets, flushing sewers, extinguishing fires, constructing new public works, supplying drinking and ornamental fountains, and serving municipal buildings, schools, hospitals, asylums, etc., should also be paid for by general taxation at substantially the same rate as charged to private consumers.

In the case under consideration, it is probable that fully 10% of the gross supply will be used for the public purposes mentioned, in which event the quantity will amount to about 300 000 000 galls. per year. As will be seen subsequently, the cost of the water is about 5 cents per 1 000 galls., so that the value of the quantity mentioned becomes $15 000 per year.   Finally, there is the proportional part of the annual contribution of $32 000 to the aforesaid sinking and renewal fund, which should be paid by general tax; and as it may be assumed that not less than one-third of this account relates to general public purposes, such part should accordingly be about $11 000.   The total yearly amount to be raised by general tax is, therefore, as follows:

1. For interest on proportional part of bonded debt
   incurred for fire and future purposes............ $75 000
2. For proportional part of annual operating expenses.   10 000
3. For value of water used for general public purposes.   15 000
4. For proportional part of annual contribution to
   sinking and renewal fund......................   11 000

          Total...................................... $111 000

The total annual expenses, however, were found to be $232 000; hence, if $111 000 be obtained by general taxation, the remainder, $121 000, should be secured from the private consumers, and the question of the proper charge for the water by meter measurement is reached. As stated in the outset, the average daily consumption in the city is

8 000 000 galls., of which a certain percentage is lost by leakage in the pipe distributing system and its appurtenances. For the present, it may be assumed that such leakage is at the average rate of 3 000 galls. per mile of pipe per day, thus giving a loss in 150 miles of 450 000 galls. per day, or about 5.6% of the gross consumption. There is also a certain loss due to under-registration of meters for which allowance must be made, and no great error will probably be made if the same is taken at 4.4% of the gross consumption, it being assumed that all service pipes are metered. The total loss by these two causes is, therefore, 10%, thus leaving 7 200 000 galls. per day, or 2 628 000 000 galls. per year, available for public and private use; and as the sum of $121 000 is to be obtained by the sale of this quantity of water, the cost price accordingly becomes about 4.6 cents per 1 000 galls. To provide for other contingencies of loss and errors in the various estimated quantities, such cost price may be considered as at least 5 cents in this case.

Fire Streams and Leakage.—In connection with the foregoing financial questions, it also becomes of interest to investigate somewhat more definitely the demands which are made upon the water-works system for fire purposes, and the losses by leakage from the distributing pipes and their appurtenances. The most recent discussions of these two subjects with which the author is acquainted are contained respectively in the valuable paper* on "The Protection of a City against Fire," by John R. Freeman, M. Am. Soc. C. E., and in the equally valuable paper† on the "Consumption and Waste of Water," by Dexter Brackett, M. Am. Soc. C. E. In the former, Mr. Freeman gives his own estimate of the number of fire streams which may be required simultaneously in American cities of various magnitude, together with similar estimates by Messrs. J. Herbert Shedd and John T. Fanning, Members Am. Soc. C. E. These estimates are all in tabular form, and may be combined as on the next page, it being understood that the streams will each discharge from 250 to 200 galls. per minute, and that this number refers to use upon large fires in the commercial and manufacturing districts.

The fifth column of the following table contains the author's estimate of the probable greatest number of such streams that may be

* See *Journal* of the New England Water-Works Association, Vol. vii.
† See *Transactions*, Vol. xxxiv, p. 185.

TABLE EXHIBITING ESTIMATED NUMBER OF FIRE STREAMS REQUIRED SIMULTANEOUSLY IN AMERICAN CITIES OF VARIOUS MAGNITUDES.

Population of community.	NUMBER OF FIRE STREAMS REQUIRED SIMULTANEOUSLY.			
	1 Freeman.	2 Shedd.	3 Fanning.	4 Kuichling.
1 000	2 to 3	....	....	3
4 000	....	....	7	6
5 000	4 to 8	5	....	6
10 000	6 to 12	7	10	9
20 000	8 to 15	10	....	12
40 000	12 to 18	14	......	18
50 000	....	....	14	20
60 000	15 to 22	17	....	22
100 000	20 to 30	22	18	23
150 000	....	....	25	34
180 000	....	30	....	38
200 000	30 to 50	....	....	40
250 000	....	....	....	44
300 000	....	....	....	48

required, as deduced from the replies to a recent inquiry addressed by him to the fire department chiefs of about fifty American cities.   For more easy comparison, this table is represented graphically in Fig. 1. It may also be remarked that rare disasters, like the great conflagrations at Chicago, Boston, Lynn, etc., are not considered in any of these

DIAGRAM SHOWING RELATION BETWEEN NUMBER OF INHABITANTS AND NUMBER OF FIRE STREAMS IN AMERICAN CITIES.

REFERENCE
FREEMAN (y MAX.)
FREEMAN (y MIN.)
SHEDD.
FANNING.
KUICHLING.

NUMBER OF STREAMS. (y)
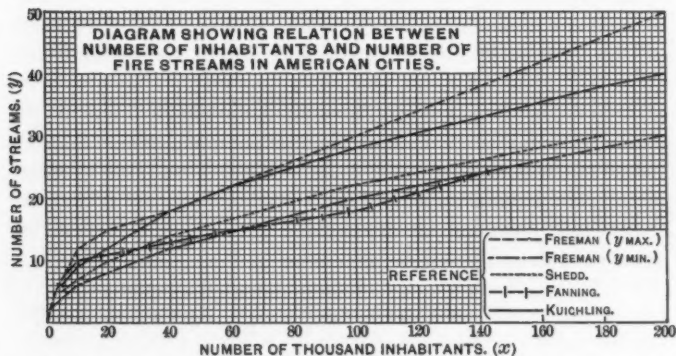
NUMBER OF THOUSAND INHABITANTS. (x)

FIG. 1.

estimates, as the local fire departments are usually unable to manage a much larger number of streams without help from neighboring communities.

    To determine conveniently the ratio which the total delivering capacity of the distributing system should bear to the quantity

required for ordinary purposes alone, the relation between the number of inhabitants of the city and the required number of fire streams, as well as the ordinary consumption of water, should be expressed analytically. For the former, the author has deduced from the preceding table the following expressions, in which y denotes the required number of streams and x the number of thousand inhabitants:

For Freeman's data: $\begin{cases} y\ \text{min.} = 1.7\sqrt{x} + 0.03\,x \\ y\ \text{max.} = \dfrac{x}{5} + 10 \end{cases}$ .... (1)

For Shedd's data: $y \quad = \sqrt{5\,x} = 2.24\,\sqrt{x}$ .... (2)

For Fanning's data: $y \quad = \dfrac{x}{10} + 9$ .... (3)

For the author's data: $y \quad = 2.8\,\sqrt{x}$ .... (4)

while for the average ordinary consumption of water, expressed in gallons per head and day, q, Mr. Coffin's formula, as given in his paper previously cited, may be taken:

$$q = 40\,x^{0.14} \quad\quad\quad\quad\quad\quad\quad\quad (5)$$

A glance at this table or the diagram shows that the author's estimates of y are generally intermediate between the greatest values given by Mr. Freeman and those given by Messrs. Shedd and Fanning; and as the corresponding expression (4) is simple in form, it may be used conveniently in combination with (5), after reducing both to discharge in gallons per minute. For this purpose it will be assumed that each fire stream delivers 250 galls. per minute, and that in dealing with the quantity required for ordinary consumption, the maximum rate of such consumption during the business hours of the day should be considered instead of the average rate for 24 hours. This maximum rate is usually about 1.5 times the average, and hence the total capacity of the main distributing system for a given number, x, of thousand inhabitants, expressed in gallons per minute, should be:

$$Q = \left\{ 250\,(2.8\sqrt{x}) + \frac{3}{2}\,\frac{40 \times 1000}{1440}\,x^{1.14} \right\}$$

$$= 250\left(2.8\sqrt{x} + \frac{x^{1.14}}{6}\right) \quad\quad\quad\quad (6)$$

while the capacity required for ordinary consumption alone is:

$$q_1 = 250\,\frac{x^{1.14}}{6} \quad\quad\quad\quad\quad\quad (7)$$

and that for fire purposes alone is:

$$q_2 = 250\,(2.8\sqrt{x}) \quad\quad\quad\quad\quad\quad (8)$$

The ratio of the total capacity to the quantity needed for ordinary purposes is thus found to be:

$$m_1 = \frac{Q}{q_1} = 1 + \frac{16.8}{x^{0.64}} \quad \dots \dots \dots \dots \dots \dots (9)$$

and inasmuch as the required deliveries Q and q_1 are proportional to the squares of the respective diameters D and d, the following values of the ratios $\left(\dfrac{Q}{q_1}\right)$ and $\left(\dfrac{D}{d_1}\right)$ are accordingly obtained for different values of x, or populations of different magnitude.

For $x =$	50	100	150	200	250	300
$m_1 = \dfrac{Q}{q_1} =$	2.374	1.882	1.680	1.566	1.491	1.437
$\dfrac{D}{d_1} =$	1.54	1.37	1.30	1.25	1.22	1.20

The cost per lineal foot of the usual cast-iron distributing pipes laid in place, however, may in general be expressed by the formula, $s = a + bd^n$, in which the exponent n is unity for the smaller sizes up to a diameter of about 10 ins., while for larger sizes it becomes about 1.4; hence allowance must be made for this fact in computing the relative cost of the system when provision is to be made for fire purposes. It is therefore seen by this general method of analysis that the estimate of one-third of the original cost of the works for fire protection is not excessive for cities of from 100 000 to 300 000 inhabitants.

With regard to the invisible or undiscoverable leakage from the distributing system and its appurtenances, such as fire hydrants, stop-valves and the street cocks on the service pipes, little information is as yet available, especially in the case of large cities. In the papers previously cited, both Mr. Brackett and Mr. Coffin have given some interesting data about the quantity of water not accounted for in the extensively metered towns of Yonkers, N. Y., Milton, Newton, Welles-ley and Fall River, Mass., and Woonsocket, R. I., and have shown that such quantity ranges from 30% to 50% of the whole supply. It appears, however, that some public uses of water and the slip or under-registration of the meters were not included in the estimates, so that the entire loss in these cases cannot fairly be attributed to leakage. In Berlin, on the other hand, the water-works authorities claim

that only about $2\frac{1}{2}\%$ of the supply is lost by leakage, and the question naturally arises why such loss should be so large in American cities and so little in the German capital.

An examination of the different elements of the problem, however, leads to the conclusion that it is entirely improper to measure the leakage by a percentage of the supply. The quantity of water passing through a leaky pipe bears no relation whatever to the loss, and the latter depends only on the size and number of the orifices and the pressure. Thus in a pipe from which no draft is made, the leakage is 100% of the discharge; whereas with a heavy draft, the same loss may become only a small fraction of 1 per cent. A more rational method of expressing leakage is to state the quantity lost in terms of some unit of length and time, such as gallons per mile per day; and when this is done, many apparent anomalies will probably shrink to small proportions.

It should be understood that the leakage here referred to is limited to that which does not show on the surface of the ground, and the individual components of which cannot be detected by the most careful inspection. Loss by wilful waste on the part of consumers and by breakage of pipes is distinctly excluded from present consideration, since the former may be corrected by the use of meters, and the escape of a comparatively large quantity of water at a single point generally renders itself manifest after a short time. The inquiry may therefore be restricted to the loss due to the sweating or slight dripping of the pipe joints, valves of fire hydrants, stuffing-boxes of stop-valves, badly ground taps and curb cocks, and defective joints in service pipes.

From close observation of thousands of water pipe joints and fixtures in various localities, both when first laid and after having been in use for years, the author has reached the conclusion that a discharge of one drop per second from each joint, five drops from each hydrant and stop-valve, and three drops from each service pipe, including tap and curb cock, represents a fair measure of the average undiscoverable leakage in a well-constructed distributing system. As the size of a drop of water, however, depends upon the form and magnitude of the surface from which it falls, a number of experiments were made by the author to determine the weight and volume of one hundred drops falling from a cast-iron surface similar to that of a pipe socket, from

which it was found that one such drop per second is equivalent to about 3 galls. per day. On this basis, and with the assumption that on the average there are 504 pipe joints, 12 hydrants, 10 stop-valves and 100 service pipes per mile of distributing pipe, the leakage will amount to 2 742 galls. per mile per day, or in round figures, say from 2 500 to 3 000 galls. per mile per day.

In comparing these figures and the observed losses at the several places mentioned in the papers of Messrs. Brackett and Coffin, it should be noticed that in all of the cases, more or less unmeasured water was used for public purposes, and no account was taken of the under-registration of the meters; furthermore, there appears to be much uncertainty as to the actual delivery into the distributing pipes, owing to the variable allowance made for slip in the pumps. Considering that with the exception of Berlin and Fall River, most of the cities are small, and that the unmeasured amounts used for public purposes may easily be relatively large, it may be assumed that 10% of the given total delivery, or about 4.5 galls. per inhabitant per day, is thus consumed; and as most meters failed to record the entire quantity of water passing through them, especially for small discharges such as occur from defective house fittings, it will probably be fair to assume that 5% more is attributable to under-registration. These two items may also include the possible error in the allowance for pump slip. For convenience of examination, the essential data may now be arranged in the table on the next page, the last column of which contains the computed leakage.

In the case of Berlin, it has been assumed in the table that only about 2.5% of the total delivery is lost by leakage from the distributing pipes and appurtenances, not because there is any good proof that so slight a leakage exists in that city, but rather to indicate the author's lowest estimate of such loss in a large system, which has been in use for many years, but is maintained in the best possible condition. The claim that only 2.5% of the entire output of the works cannot be accounted for, and that this also includes under-registration of the meters, appears entirely unjustifiable to the author, since large quantities of water are used in Berlin for public purposes, which must necessarily be estimated on somewhat coarse lines. To those who are familiar with the details of municipal water-works, such a close balancing of the accounts cannot fail to be suspicious.

TABLE SHOWING UNACCOUNTED LOSSES OF WATER IN VARIOUS PLACES, TOGETHER WITH ESTIMATES OF LEAKAGE FROM DISTRIBUTING PIPES AND APPURTENANCES.

Locality.	Year.	Number of miles of distributing pipe.	Total delivery in gallons per day. (Q_0)	Quantity not accounted for, being for public uses, under-registration of meters, and leakage of pipes.		Estimated leakage in distributing system, being balance left after deducting from (Q_1) 10 per cent. of (Q_0) for unmetered public uses, and 5 per cent. of (Q_0) for under-registration of meters.	Computed leakage from pipe system in gallons per mile per day.
				Gallons per day. (Q_1)	Per cent. of total delivery.		
Milton, Mass.	1893.	18	128 529	62 687	48.8	43 408	2 411
Newton, Mass.	"	105	1 288 000	595 600	46.2	402 400	3 832
Fall River, Mass.	"	64	2 217 370	942 870	42.5	610 264	‡9 535
Woonsocket, R. I.	"	33	*3 348 000	*748 000	22.4	245 800	‡7 448
Yonkers, N. Y.	"	43	2 623 760	1 010 000	38.5	616 436	‡14 336
Berlin, Germany	1889.	411	20 000 000	800 000	4.0	†534 000	1 300
Author's general estimate.	......	......	....	....	....	....	{ 2 500 to 3 000

* Average for six months from March 1st to September 1st, exclusive of amount used for street watering, fountains, etc., for which a definite estimate is given.

† Least probable quantity as estimated by author, being about 2½% of total delivery.

‡ These quantities are regarded as highly excessive, and are doubtless due to errors in the premises.

With reference to the leakage in the other cities, especially Yonkers, Fall River and Woonsocket, it is proper to state that the large figures exhibited in the last two columns of the foregoing table are purely tentative, and that a closer examination of the actual conditions will doubtless reveal a far better general state of the works than might be inferred from the submitted analysis. The results, however, are instructive, in so far as they point to the exercise of the utmost care, not only in the original construction and maintenance of an extensive distributing system, but also in accounting for the water delivered therein.

DISCUSSION.

JAMES OWEN, M. Am. Soc. C. E.—The varying character of the Mr. Owen. water supply in municipalities will materially affect the cash value of the plant. Of two similarly situated towns, one furnishes a supply under a head of 60 to 70 lbs., while the other furnishes the water at 10 to 15 lbs. pressure. It can be readily seen that there is a greater value to the community in the water at the higher pressure in the saving of apparatus for the fire department, a point not mentioned in the paper.

Another point is the necessity in some cities of furnishing cheap water for manufacturing purposes. This is a self-evident business proposition, and there are many cities which have induced manufacturers to settle in them by furnishing practically free water, the cost of which is met by the taxpayers at large. In other cities the higher rates are insisted on, which has a detrimental effect on the growth of the manufacturing industries.

In one city the cost of laying pipes through a street is assessed equally on unimproved and improved property, which puts the introduction of water carriage on the same basis as the improvement of a street. The authorities say they introduce the privilege of water, and the property should pay for it. If this principle is extended it will limit the bonds to a large extent, and is an excellent practice.

Another feature of this subject is the sentiment in a community as to the standard of the water supply it should have. A community owning its plant is much more tolerant of imperfections in the service than are people who live where there is a private water supply. It is part of their own trouble, and they are willing to let it run along. It is safe to say that in New York City some years ago, when very few houses had water up to their third stories, a private company serving them in that way would not have been tolerated 24 hours.

RUDOLPH HERING, M. Am. Soc. C. E.—It is hardly just to apply the Mr. Hering. same rules for the valuation of water-works property and service in all sections of the country and in cities of different sizes. Rules may be properly used in a well-established city which would be not at all applicable in a new and small city, just beginning to grow.

The point raised concerning the bonding of different parts of a water system for different periods is a good one; for example, the cost of a large storage reservoir, masonry aqueduct or other durable portion of the works may be met fairly and properly by an issue of bonds running longer than those issued to cover the expense of more perishable portions, such as pumping machinery, which may wear out in twenty years or be replaced by new engines of greater economy in operation.

The author has done well to refer to the gain to property through the possession of water-works by reason of the reduced fire insurance rates on all the property in the city. This is a feature rarely discussed,

Mr. Hering. but in view of the author's explanation of the method of estimating this saving, it should be considered hereafter in every valuation of a water-works.

Mr. Tribus.   L. L. TRIBUS, M. Am. Soc. C. E.—The influence of water-works on insurance rates was considered in all cases in the preliminary discussion of works in which the speaker had been interested, and the representatives of insurance companies agreed to grant a reduction of 15% to 30% in the rates when the systems should be in operation and giving adequate fire protection. When this condition was attained, they usually made a reduction of 10% to 20% with much reluctance.

CORRESPONDENCE.

Mr. Hawley.   W. C. HAWLEY, Assoc. M. Am. Soc. C. E.—The City of Atlantic City, N. J., on August 1st, 1895, purchased the plants of the Atlantic City Water Company and the Consumers' Water Company. Five per cent. 30-year bonds to the amount of $775 000 were then issued to pay for them; and $4\frac{1}{2}\%$ 30-year bonds to the amount of $100 000 have since been issued for extensions and improvements, making a total bonded indebtedness of $375 000, with interest charges aggregating $43 250 per year. For certain reasons both plants are operated, and hence the annual operating expenses, in which are included management, repairs, minor additions and pumping expenses, are relatively high, about $29 000. The amount decided upon as an annual payment to the sinking fund is $22 580, making the total annual revenue needed for the operation of the water-works $94 830.

The equitable division of this charge between the water consumers and the tax-payers was a complicated problem.

The population of Atlantic City varies from the strictly resident population of about 21 000 during the fall and winter months to more than 150 000 during parts of the month of August. During the period of competition between the water companies, waste had been encouraged rather than restricted, and when the city purchased the plants the per capita pumpage per day was about 250 galls. It was therefore necessary to restrict this waste by the introduction of meters, or else to expend a large sum for additional pumping machinery. About 1 500 meters were purchased and placed in service with most excellent results, and it is intended in the next two or three years to meter all consumers. The introduction of meters necessitated a change from the assessed rates to minimum meter rates, with additional charge for all water used in excess of the amount to which the minimum entitles the consumer. This change made it impossible to estimate at all closely the probable revenue of the department, and the meter rates were placed at 18 and 14 cents per 1 000 galls. For

the first year after the purchase of the works by the city there was no Mr. Hawley. money raised by general taxation for the water department. In the second year there has been about $12 000 so raised. The first lot of excess meter bills, sent out in February of this year, forced to the attention of the people the need and the justice of raising part of the revenue required by the water department by general taxation. It was argued that all water used for public purposes, fire protection, street sprinkling, schools, etc., should be paid for by general taxation; that all improved property, which, by the use of artesian wells or cisterns, avoided the payment of water rates, and all unimproved property, the value of which is increased by the very existence of the water-works, but which pays nothing for water, should be made to bear their share of the cost of maintaining the water-works. It was therefore decided that there should be raised annually by general taxation, and turned over to the water department, an amount equal to the value of the water used for public purposes, estimated to be $10 000, and the amount required to be paid into the sinking fund, $22 580, a total of $32 580.

By estimating the probable average population per month, and figuring on a daily per capita use of 70 to 50 galls., and allowing for leakage, which on account of local conditions is considerable, it was found that a meter rate of 12 cents per 1 000 galls. would probably make up the balance needed, $62 250, this on the supposition that all water is sold by meter. The 12-cent rate goes into effect August 1st, 1897.

It is interesting to compare the results thus obtained with those obtained by applying the principles brought out by the author. On the 2% basis the payment into the sinking fund each year should be $17 700. The payment made, $22 580, is $4 880 in excess, which will provide in thirty years a fund of $244 000, which may be used to renew perishable parts. The annual charges are, as previously stated, as follows: Payment into sinking fund, $22 580; interest, $43 250; operating expenses, $29 000; total, $94 830.

The present plants are practically at the limits of their respective capacities. It would not be fair therefore to charge half of one-third of the interest because of increased cost of works to provide for future growth. Therefore,

One-third of interest charged to cover increased cost of plant to provide for fire protection........ ...	$14 400
Proportional part of operating expenses to be paid by general taxation for maintenance of pipes, hydrants, etc., would be smaller in this case, say..	2 000
Water used for public purposes....................	10 000
One-third of annual payment to sinking fund.......	7 500
Total..............................	$33 900

Mr. Hawley.   This compared with $32 580, the amount now annually to be raised by general taxation, shows a closer agreement than might have been expected.

Mr. Stenger.   E. STENGER, Assoc. M. Am. Soc. C. E.—It is not apparent why the author, in giving his formula on page 7, should deviate from the usual formula for determining the amount of an annuity. The usual expression written in the terms he employs would be:

$$s = \frac{r}{100 \left(1 + \dfrac{r}{100} \right)^n - 100} \, p$$

The equation gives the amount of the annual sum to be paid into the fund at the end of each year for a period of n years in order to produce the required principal at the end of the period; whereas the author's formula would give the annual sum to be paid in at the beginning of each year of the period in order to produce the principal at the end of it. The shorter the period, or the greater the rate of interest, the greater will be the difference between the results of the two formulas.

Mr. Coffin.   FREEMAN C. COFFIN, M. Am. Soc. C. E.—The paper is very valuable as bringing into prominence among engineers the somewhat neglected question of the management of municipal water-works from the financial side, and in emphasizing some points that are not generally given the consideration that their importance demands. Especially satisfactory is the strong position that the author takes in opposition to the endeavor to make a profit from the operation of the works or to the practice, which is sometimes advocated, of charging the expenses of some other department of municipal service to the maintenance account of the water department.

There seems to be a prevailing impression that the water service is distinctively revenue producing, and that it stands by itself in this respect, when compared with other forms of municipal activity, such as the construction and maintenance of sewers, roads, schools, etc. Careful analysis will reveal no fundamental reason for this belief. On the contrary, when undertaken by the municipality it stands on exactly the same footing as the others, and is different from some of them only in the fact that the service to the individual can be located and measured, as it cannot well be in the case of roads, bridges and poor-relief.

Even this is not true of many municipal activities. The service rendered the individual by schools and sewers can be as definitely and justly placed and measured as that rendered by a water supply. It may be said in reply that there is a general benefit to the community derived from schools and sewers besides that accruing to the individual. This is true, and it may well be that this general benefit far outweighs the aggregate of the particular benefits, and thus obliter-

SCALE OF REVENUE IN PERCENTAGE OF FIRST YEAR'S RECEIPTS

Fig. 2.
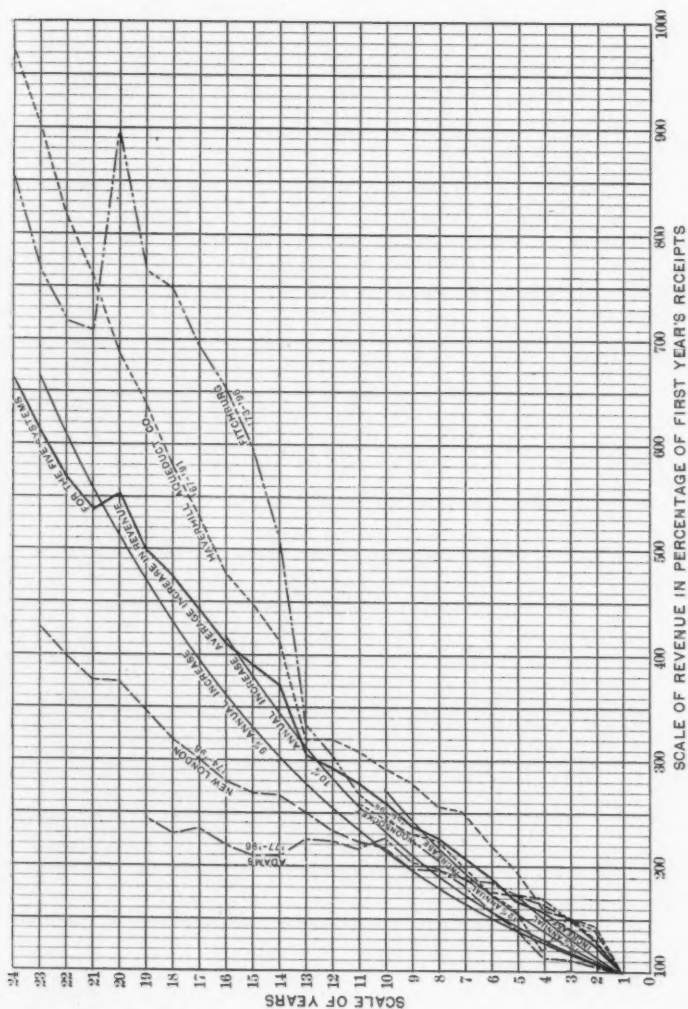
Mr. Coffin. ates any injustice that is caused by the inequality of the amount of service rendered the individual. If this is true of such agencies, it is no less true of a suitable supply of water for domestic, manufacturing and fire purposes. An extremely strong case can be made for the supplying of water free, and meeting the maintenance account from the general taxes. The strong and valid objection to this course is that it would deprive the department of the only available and effective weapon of defence against waste of water.

The question of waste prevention is so vital that the above objection is a sufficient reason for continuing the present method in some form. If there is any injustice in the general practice, it is in the direction of making the consumer pay too large a proportion of the maintenance and the taxpayers too small a proportion. The author shows the benefit to taxpayers resulting from the reduction of cost of fire insurance. The benefit from a water supply to owners of land upon which there is no insurable property is also great. It is notorious that this class of property holders does not, as a rule, pay excessive taxes.

To apportion the maintenance expenses more fairly than is usual at present, a careful estimate of the cost of maintaining a supply of water for domestic and manufacturing purposes alone should be made, and the same for a fire service alone, and the ratio that each bears to the sum of both is the proportion of the maintenance of the combined system that each should pay. This ratio would probably be found, upon an average, to be about 50% for each. This method would reduce the amount paid by the consumer in many cases, but it still leaves unconsidered the general benefits derived from a water supply system.

In advocating the provision of a sinking fund to cover the payment of the bonds at maturity, and the depreciation of the plant in the same term of years, the author advocates actual payment of the debt caused by construction in such term of years, or in one generation; that is, under such a course, at the end of thirty years the bonded debt would be paid and the municipality would, at the rate advocated by him, have in hand a sum of money of equal amount. While this is, of course, a very desirable condition of affairs for posterity, the adoption of such a policy would place a heavy burden upon new works. It is well known that very few works during the early years can do more than meet the necessary expenses of operation, interest and sinking fund to pay for the bonds, without the appropriation of larger sums from the general taxes than could properly be required.

It is also known that the revenue in a great majority of cases increases faster than the maintenance expenses. Fig. 2 shows the average increase in the revenue of five water-works systems of which records were given in their reports. This diagram shows that the

average increase of revenue in these five works is 15% annually for the first five years, 12% for the first nine years, 10% for the first sixteen years, and 9% for the first twenty years. Mr. Coffin.

If such is the case, should it be considered essential for every system to make such provision as the author advocates ? If a sinking fund is created to extinguish the bonded debt at maturity, although it may be desirable, is it necessary to make further provision for depreciation ? If it is necessary, is not thirty years too short a term to use as the average life of a well-built plant as a whole ? If a sinking fund is based upon the total cost of construction, it covers much that in a plant kept in good repair is practically indestructible; dams, reservoirs, basins and all improvements to drainage areas belong in this class. Taking all of these items into consideration, with that of the length of life of cast-iron pipe, which forms so large an item, forty years is perhaps nearer the average life of water-works plants than is thirty years.

In making provision for maximum draft upon the piping system the author uses one and one-half times the average rate of consumption as the maximum consumption, to which he adds the estimated draft for fires. The writer has commenced a study of the time distribution of draft or consumption. The data at present collected and examined indicate a great difference between the average rate of daily consumption, as obtained by dividing the total annual consumption by three hundred and sixty-five, and the rate of draft at any particular time in the year, month or day.

From the records of thirteen cities and towns the average daily consumption for each month, in percentages of the average daily consumption for the year, is found to be as follows:

January	.... 87.20 per cent.	May	.... 99.80 per cent.	September.	109.40 per cent.
February	... 89.00 "	June	.... 114.00 "	October.	... 103.00 "
March	...... 88.65 "	July	.... 123.00 "	November.	.. 92.10 "
April	.... 89.70 "	August	.... 113.50 "	December.	.. 88.70 "

Total.... 1 200 per cent. ÷ 12 (months) = 100 per cent.

It will be observed that to systems depending upon the ordinary flow of a river or stream, or to those in which the storage is small, whether above or below the ground, the above table presents an important condition. In the five months when the natural flow is at a minimum, the average daily draft is $12\frac{1}{2}$% in excess of the average for the year. In designing storage systems this factor should be considered and storage provided for a draft through the dry months, greater than the average. In the records of one system, as shown by the register of heights of water in the stand-pipe, and the pumping records, the following is found:

That the rate of draft in the month of maximum consumption was 122% of the average rate for the year. That the rate in the maximum

Mr. Coffin. week was 134 per cent. That the rate in the maximum day was 155 per cent. That the rate in the maximum hour of that day was 333% of the average rate. That the rate in the maximum two continuous hours was 312 per cent. The rate in the minimum hour of same day was 45 per cent. On three days that were studied in different portions of the same month (August) the average rate from 10 A. M. to 3 P. M. was 230% of the average rate for the year. It is quite probable that the rate of draft for short periods of several minutes at a time was greater than any of the figures given above.

The records of another system show results but slightly less. It is possible that data for a greater number of weeks would modify these figures. The system from which these records were taken did not, however, show as great percentage of draft in July and August as a number of others of the thirteen that furnish the figures given in the preceding table.

If the foregoing figures represent the usual conditions, twice the average rate would be a very conservative estimate of a rate of draft that would continue over periods of time of such length that there is strong probability of fires occurring during them.

Mr. Kiersted. W. KIERSTED, M. Am. Soc. C. E.—The paper deals with a very interesting and important phase of the water-works question. The author in his treatment of the subject has brought out in a very clear manner the important principle that there is a community as well as an individual interest embraced in the ownership of all public works, and has endeavored to apply this principle specifically in an effort to evolve a plan of water-works financiering, which admits of an equitable apportionment of the cost of constructing and supporting a water-works plant among the variety of interests which are served. Thus each individual of a community is made to contribute his proportion towards the acquirement and general support of a water-works, in accordance with the public benefits derived therefrom, through a general tax levied upon the community, and in accordance with the individual advantages which he may enjoy as a water consumer in proportion to the amount of water consumed, and in accordance with an equitable division of this cost between the present and future generations.

While there can be no doubt as regards the fundamental principle of water-works financiering embracing the dual interest of the community and the individual, yet the plan of applying this principle, as outlined by the author, involves a classification of the several portions of a water-works property according to the degree of permanency of construction, which in practice it is not always easy to accomplish. It seems to the writer that the author's plan of financiering must apply more to large, wealthy and commercially developed cities after many years of ownership of a water-works property than to those cities

which are striving to develop their resources, or which have recently Mr. Kiersted. acquired possession of such a property.

Ordinarily a city raises the money to invest in the original construction of a water-works, through an issue and sale of bonds. In some states, at least, statutory provisions limit the life of municipal bonds to twenty or thirty years, and compel the creation and maintenance of a sinking fund which can be used only for the extinguishment of the bonded debt at maturity. The wise purpose of such a law can scarcely be doubted, as, by compelling each generation to shoulder its own burden of debt, it encourages judicious expenditures of public funds and tends to prevent the handing down of a heritage of complicated finances for the municipality of a future generation to unravel. It imposes a wholesome restraint upon a progressive city, irrespective of size, and should continue to do so until that city shall have acquired independent wealth and prosperity through the permanent development of its natural trade resources, and shall have become entitled through accumulating experience in the management of municipal affairs to more liberties in the use of its credit and power of taxation than heretofore. It compels the extinguishment of the debt covering the original cost of the water-works within the limit of life of one generation, regardless of the fact that the several portions of the property may be of such a degree of permanency of construction as to serve efficiently one or more succeeding generations. A city so restricted in the use of its credit could scarcely settle down at once to a definite system of financiering, no matter how safe, equitable and economical it may be; and it could scarcely be expected to anticipate future requirements to any marked extent in the original construction of its water-works, or to provide a depreciation fund for renewals, otherwise than would be found necessary in order to maintain the plant of a capacity to supply the current demands of the community.

Thus a future generation may come into possession of a property largely free from debt, but in a more or less deteriorated condition, but that generation may use the available credit and taxing power of the city to renew the seriously deteriorated portions of the plant, to extend the water service, and to enlarge slightly or reinforce the more substantial portions of the property in anticipation of probable future requirements.

Thus, in the writer's opinion, many cities in defraying the expenses of constructing a water-works plant, and in equitably proportioning the necessary tax for the support of such a property between a general tax and a water-consumer tax, and in creating special funds and in diverting portions of the revenue thereto, must be controlled in their methods of financiering very largely by the statutory laws fixing the amount, character and duration of its debt-making power and of its

Mr. Kiersted. debt, regardless of the question of the rate of deterioration of the perishable portions of a water-works plant, or of an equitable division of the cost of constructing the more permanent portions among several succeeding generations.

While the writer is not disposed to take exceptions to the principles of water-works financiering as developed by the author, still he thinks that the application of those principles must conform to the varied, natural and commercial conditions and legal restrictions affecting the construction and maintenance of a water-works property in different sections of the country, and in particular instances must receive modification from time to time in order to conform to the changing conditions, privileges and requirements of a progressive city, thus advancing by stages toward such a proper standard of sound and consistent water-works financiering as the author has developed.

Mr. Loweth.   CHARLES F. LOWETH, M. Am. Soc. C. E.—The writer believes that imperfect pipe systems are responsible for a large waste or leakage of water.   The estimate in the paper of 2 500 to 3 000 galls. of leakage per day per mile of pipe, "in a well-constructed distribution system," he believes is excessive.   As a result of testing several new pipe systems, in most cases before any service connections were made, the writer has come to the conclusion that the leakage can be kept within 60 to 80 galls. per inch-mile of pipe per 24 hours, or 600 to 800 galls. per mile of 10-in. pipe line per day.

For several years past he has specified a leakage test for all new pipe systems or extensions.   The permissible leakage has been limited to from 60 to 80 galls. per day for each inch-mile of pipe line, depending upon the pressure, and inclusive of hydrants and valves, and a liquidated damage clause added to cover any excess leakage over this amount.   His observation has been that honest and experienced workmen can readily keep the leakage within this limit, especially when warned beforehand that their work will be tested.   A comparatively small amount of negligence, however, will result in a considerable excessive leakage.

A still more rational method of expressing leakage than that proposed by the author would include not only the units of length and time, but, in addition, the average size of the pipe line, such as gallons per inch-mile per 24 hours.   The table showing the estimated leakage in various places would be much more instructive if the average sizes of the pipe systems were included.

Imperfect service connections are a frequent source of leakage, especially where these are not put in under the direct supervision of the city or water company.

Mr. Williams.   GARDNER S. WILLIAMS, Assoc. M. Am. Soc. C. E.—The paper is one of particular interest to the writer at this time, inasmuch as the questions therein discussed have been under consideration in connec-

tion with the Detroit water-works during litigation and other con- Mr. Williams.
troversy for about five years.

While it is not his purpose to attempt to discuss the paper as a
whole, the results of his deductions on certain lines, and some facts
which have been collected in Detroit, throw additional light on a few
of the points raised.

The water-works of Detroit are managed by a Board of Water
Commissioners, and depend for their revenues upon, (a) the sale of
bonds when duly authorized, (b) the income from the sale of water, (c)
an appropriation of approximately $75 000 annually, raised with the
general tax levy. In addition to these items the Board is the bene-
ficiary of a bequest from a former member of it to the extent of about
$5 000 annually at present, which is required to be expended in
beautifying the grounds around the pumping station. From these
revenues the Board is charged with the maintenance, extension and
operation of the system, and the payment of bonds and other indebted-
ness, but is not responsible for the furnishing, setting or care of
hydrants for fire-extinguishing purposes, nor for horse troughs, the
money so expended being raised with the annual tax levy and con-
trolled by the Fire Commission and the Board of Public Works. The
Board of Water Commissioners furnishes without further compensa-
tion the water for fire-extinguishing and for the use of the Fire De-
partment. The water supplied for all other municipal purposes,
except street and sewer flushing and horse water troughs, is paid for
by meter measurement or in proportion to an estimated consumption.
This includes fountains and other uses in the public parks. From
July 1st, 1891, to July 1st, 1897, no charge was made for the use of
water in lawn sprinkling unless the premises were metered, and since
July 1st, 1894, no assessment has been put upon laundry tubs except on
metered premises.

The Fire Commission, in addition to about 2 700 hydrants and 560
reservoirs connected to the water-works system, has an auxiliary fire
system in the business portion of the town, composed of pipe lines
with hydrants attached, extending from the river front, at right angles
thereto, in various streets of the more extensively built-up part of the
city. These lines are supplied when used by a fire boat which lies at
about the center of the river front, and connects with whatever line is
required in response to an alarm. The pumps on this boat are rated
at 30.) 000 galls. per hour capacity.

The pressure maintained upon the water-works mains is so low that
auxiliary steamers are a necessity in all parts of the city, and in all
cases when a steamer takes water from a hydrant or reservoir a report
is furnished to the Water Department stating the time in service, the
pressure carried, the length and size of hose used, the number of lines
and sizes of nozzles, as well as the pressure upon the suction when the

Mr. Williams. engine is not pumping, and when it and all other engines are working. The last two pressures are of value in determining the effectiveness of the distribution in time of fire. From the remainder of the data so furnished, the quantity of water thrown by each engine is computed according to the tables and formulas of John R. Freeman, M. Am. Soc. C. E.*

Similar information is available regarding the fire boat's work, and has been utilized in this connection.

With this material as a basis, the statistics having covered a period of three years for all fires, and of several years more as regards large fires, it is possible to approach the problem of the cost of fire protection on a somewhat different side from that treated by the author.

The table on page 33 gives in concise form data that are of interest in the consideration of this subject.

From all this it appears fair to assume that the maximum hourly fire consumption in Detroit, including the supply from the fire boat, will be about 600 000 galls., while the maximum hourly consumption from all other causes has been practically 3 000 000 galls. If this city is assumed to be typical of others of similar size, it follows that the maximum hourly supply to be provided to cover all requirements would be 3 600 000 galls. When, however, it is considered that these maxima have only been reached once in the history of the works, the chance of the two occurring simultaneously becomes so remote that it seems entirely warrantable to neglect such a possibility. Actually, in 1895, which is remarkable above all years in the history of these works for excessive consumption, both in hot and in cold weather, the hourly consumption exceeded 2 400 000 galls. on 426 occasions, and exceeded 2 600 000 galls. on 118 occasions, while in 1896 it never exceeded the former amount. It seems therefore reasonable to assume, in such a case as this, that so far as machinery, supply mains and intakes are concerned, those which are sufficient for the ordinary demands will also be sufficient for fire service. The admission of this proposition excludes from the charge to fire construction all machinery and intakes, and all mains of greater diameter than 12 ins. in a properly designed system. While it is possible to conceive a system in which this would be a minimum limit, below which a certain part of the construction must be charged to fire service, it would be one radically different from the ordinary, and only encountered in some sea-inclosed city like New York or old Boston; for where, as in the ordinary city, the business center is on a line through the geographical center and the pumping station at one side, it must follow that the mains supplying the territory beyond the business center, by a proper arrangement, can be made to furnish fire protection to the latter, that being the only point where a maximum fire can occur. For example, if the water for

---

* See *Transactions*, vol. xxi, p. 426.

TABLE No. 1.

Mr. Williams.

	1894.		1895.		1896.	
	Families.*	Persons.†	Families.	Persons.	Families.	Persons.
Inhabitants......	50 357	258 834	51 857	266 545	54 301	279 107
Consumers	49 912	256 548	51 426	264 330	53 901	277 051
CONSUMPTION.‡	Gallons.		Gallons.		Gallons.	
Yearly { Total...	13 649 779 605		14 698 451 954		13 254 369 371	
{ Fire§..			10 596 000		11 362 177	
Monthly—						
Max.. { Total ..	1 424 599 284 Aug.		1 432 362 622 Feb.		1 185 788 689 Jan.	
{ Fire ...	3 213 205 "		1 469 650 Nov.		2 075 095 Apr.	
Mean { Total ..	1 137 481 634		1 224 870 996		1 104 530 781	
{ Fire ..					946 848	
Min.. { Total ..	1 008 086 892 Apr.		959 152 569 Nov.		1 018 579 350 Nov.	
{ Fire ...	261 340 Nov.		360 965 Sept.		416 677 Sept.	
Weekly—						
Max.. { Total...	331 729 762		405 284 725		308 412 818	
{ Fire ...	2 093 110		1 341 950		1 696 940	
Mean { Total...	261 776 592		288 888 117		254 193 380	
{ Fire ...			203 000		217 308	
Min.. { Total...	221 497 107		215 953 595		217 474 494	
{ Fire ...	000		000		000	
Daily—						
Max.. { Total...	52 176 772		60 532 971		48 840 030	
{ Fire ...	1 894 575		945 945		1 696 940	
Mean { Total...	37 396 656		40 269 731		36 313 340	
{ Fire ...			29 000		31 044	
Min.. { Total...	28 754 582		26 861 510		27 238 110	
{ Fire ...	000		000		000	
Hourly—						
Max.. { Total...	2 772 801		2 981 934		2 360 620	
{ Fire ...	216 000		242 000		253 000	
Mean { Total...	1 558 200		1 677 905		1 516 000	
{ Fire ...			1 125		1 293	
Min.. { Total...	794 124		832 525		868 320	
{ Fire ...	000		000		000	
Daily Mean—						
Per Con- { Total	146.66		156.15		131.04	
sumer.. { Fire..			0.11		0.11+	

* By "Families" is meant the number of establishments, including boarding houses and hotels using water for domestic and culinary purposes.

† Obtained by multiplying the "Families" by 5.14, a mean ratio obtained from last four U. S. censuses.

‡ Measured at the pumps by plunger displacement, allowing about 2% for "slip." Readings of revolution counters are recorded hourly.

§ From water mains only.   All quantities given in the table for "Fire" purposes are included in the corresponding "Totals."

supplying territory beyond sections of maximum fire possibility be carried, not in one or two very large mains, as is most frequently done, but in several of medium size on different streets, both fire protection and domestic service will be served without greatly adding to the cost. To be specific, if a 24-in. main is required to supply a district beyond one of maximum fire possibility, and for ordinary service in the latter 4-in. pipe in the various streets is sufficient, the 24-in. main and 4-in.

Mr. Williams. pipe may be replaced by a 16-in. and four 12-in. mains.   From tables*
by E. B. Weston, M. Am. Soc. C. E., the cost per foot is as follows:

Cost of 24-in. $3.502	Cost of 16-in. $1.899
Cost of four 4-in. . . 1.704	Cost of four 12-in. . 4.980
$5.206	$6.879

which shows an increase of 32% for the lines so treated.   If the large
mains be laid 700 ft. apart, or on every second street, ample protec-
tion will be afforded for a city of this size, and the increased cost on
the longitudinal lines will be about 16%, while there will be no in-
crease on cross lines, whence the net increased cost of this construc-
tion will be only about 8 per cent.   This treatment continues to be
applicable until the point is reached where the territory has nothing
beyond.   The hydrants are not included in the above computation.
The value of the hydrants and reservoirs connected with the Detroit
system is about $600 000 in position, while the value of the distribu-
tion alone is about $3 600 000, or the former amount to about one-sixth
of the latter.   The aggregate valuation of these works, including
hydrants and reservoirs, is about $5 850 000.

On this basis of reasoning the charge to fire consumption would be
the following construction :

(*a*) Hydrants and reservoirs $600 000
(*b*) Increased size of pipe in outskirts amounting
    in cost to about $33\frac{1}{3}$% of $1 500 000 . . . .   500 000
(*c*) Eight per cent. of cost of distribution, less (1)
    cost of pipe in outskirts, (2) cost of force
    mains between works and business center,
    and (3) cost of large distributing mains not
    divided for fire protection = 8% of ($3 600 000
    —[$1 500 000 + 1 000 000 + 600 000]) = ...   40 000

        Total. $1 140 000

or about $19\frac{1}{2}$% of the entire construction.

If, in addition to this construction and the provisions for its main-
tenance and renewal, the cost of the water used in fire extinguishing
and the maintenance of a fire department is charged to the general
tax levy, it seems that all is done that should be for a fair and equita-
ble distribution of the burden.

The writer does not wish to be understood as saying that the
Detroit water system has been constructed on the highly ideal lines
laid down above, for it most decidedly has not, but in several instances
lines that were originally laid for the specific purpose of fire protec-

* See *Engineering News*, June 21st, 1890.

tion have come to be utilized in the general distribution for carrying Mr. Williams. water to territory beyond that in which they were laid.

The writer has had occasion to investigate with considerable care the leakage from a system of pipe comprising 3 487 ft. of 10-in., about 3 000 ft. being submerged in a river crossing, 4 700 ft. of 8-in. on land, 10 820 ft. of 6-in. on land, and 6 300 ft. of 4-in., also on land. Connected to the 8, 6 and 4-in. pipe are twenty hydrants and twelve gates, and on the 10-in. pipe are three gates. The 10-in. pipe, where submerged, was laid with special ball joints every four to seven lengths, the other joints being of the ordinary bell and spigot type. This pipe was laid in 1893, and was first tested in July, 1894, by pumping through a 3-in. disk meter. With an average pressure on the pipe of about 90 lbs., the leakage amounted to 599 cu. ft. in twelve hours, and with a pressure of about 50 lbs., tested after the higher pressure, the leakage was 277.5 cu. ft. in twelve hours.

In the fall of 1894 the 8-in. line was laid by day labor, and was tested at about 50 lbs. pressure in the open ditch, leaks being repaired before covering. In 1896 the 6-in. and 4-in. pipe were laid by contract, and the test in the open ditch was not required, although the contractor made use of it to some extent.

In November, 1896, the whole system was tested under the direction of the writer, the river crossing being investigated first.

The crossing and approaches were 3 487 ft. long, of ordinary 10-in. cast-iron pipe and contained 306 bell and spigot joints besides 49 ball joints and three gates. It was ordinarily supplied through two 6-in. disk meters. For this test a new ¾-in. disk meter was coupled in, so that by closing the gates the water passed through a 6-in. meter, then through the ¾-in. meter and finally through the other 6-in. meter to the pipe to be tested. The water was taken from the city mains, which are supplied by direct pressure. To reduce as far as possible any leakage past the 10-in. gate at the further end in the original test, a 10-in. cap had been leaded into the pipe, but for the last test two gates controlling the two branches of the pipe about 15 ft. back of the 10-in. gate were closed and then the latter was shut. The three meters were read every five minutes, and pressure gauge readings were taken at both ends of the line every minute. The pressure on the pipe at the level of the river was between 42 and 43 lbs. The record of the meters after one hour was: First 6-in. meter, 0.0 cu. ft.; ¾-in. meter, 4.15 cu. ft.; second 6-in. meter, 0.00 cu. ft.; maximum flow in 5 minutes, 0.37 cu. ft.; minimum flow in 5 minutes, 0.32 cu. ft.

This gives a leakage of 745 galls. per day. The author's estimates would give about 1 210 galls.

The test was then extended to the rest of the system, the same meters being used in the same manner, the record being taken for 20 minutes with all services shut off, from which there resulted a leakage

Mr. Williams. in the entire system, including the 10-in. line, of 4 847 galls. per day. The author's estimates would give about 6 250 galls., or deducting results from the 10-in. line, the figures would be, actual, 4 102 galls., and estimated, 5 040 galls. per day.

During this test the first 6-in. meter registered 22.2% and the second one 16.7% of the water recorded by the ¾-in. meter.

One of the most interesting features of this case was the remarkable improvement in the line after its first test, the leakage under 50 lbs. pressure in July, 1894, being 4 149 galls. per day, while in November, 1896, it was only 745 galls. per day. The meters used in both cases were meters not previously in service. It may also be proper to state that the only connection between the pipe tested and the rest of the system was through the meters, the system tested being that supplying Belle Isle Park.

The following table shows the consistency of the three meter records:

TABLE No. 2.

Period.	1st 6-in. Meter.		¾-in. Meter.		2d 6-in. Meter.	
	Cubic Feet.	Per Cent.	Cubic Feet.	Per Cent.	Cubic Feet.	Per Cent.
20 minutes, 1.45 to 2.05 P. M..	2.00	22.2	9.00	100	1.50	16.7
10 " 2.05 " 2.15 " ..	8.00	70.0	11.42	100	8.00	70.0
5 " 2.15 " 2.20 " ..	12.00	97.0	12.37	100	11.00	89.0
10 " 2.20 " 2.30 " ..	25.50	93.0	27.40	100	23.50	86.0
19 " 2.30 " 2.49 " ..	50.50	93.3	54.00	100	52.00	96.3
11 " 2.49 " 3.00 " ..	31.00	93.0	33.32	100	31.50	94.5

Mr. Kuichling. E. KUICHLING, M. Am. Soc. C. E.—It is gratifying to note that the discussion of the paper has not only established the soundness of the general principles advanced by the author, but has also elicited many interesting and valuable data relating to the operation of municipal water-works.

The suggestion that the pressure at which the water is delivered should be taken into account in estimating the value of the plant is a good one, as in most small cities the majority of fires occur in buildings of moderate height, and can easily be extinguished by hose streams taken directly from the hydrants when the water pressure in the pipes is from 40 to 60 lbs.; hence, in such cases the benefit accruing to the community from the saving in the operating expenses of the fire department and the reduction in the rates of insurance cannot fail to be greater than in cities where much lower pressures prevail. In both instances, however, the size of the distributing pipes is a very important element with insurance companies in determining how much reduction they will make in their rates.

With respect to the relative costs of the different features of a Mr. Kuichling. water-works plant which are mentioned in the paper, it was not the author's intention to imply that the numerical proportions suggested by him were applicable in all cases, or that they were to be regarded otherwise than as rough averages.   The purpose was to gain due recognition of these elements, leaving their proper numerical values to be determined from a careful study of each particular case.

So far as the sinking fund formula is concerned, it is of little consequence whether the annual payment is made at the beginning or end of the year, provided the time of making it is distinctly understood when the fund is first started.   The form of expression used in the paper is deemed preferable by the author, simply because it is customary for municipalities to levy and collect taxes at the beginning of their fiscal year, and the last payment to the sinking fund will then draw interest for a year before the fund finally matures.

Concerning the statement that in a great majority of cases the revenue increases faster than the maintenance expenses, it may be remarked that during a certain period of time such increase is to be expected, inasmuch as it rarely happens that all occupied premises abutting on the streets in which water pipes are laid will at once be supplied from these pipes.   Usually a number of years will elapse after the introduction of a system of water-works before the private wells in populous districts are wholly abandoned, and buildings are erected on the vacant lots fronting on streets where the water supply is available.   Furthermore, to encourage its general use, the charges for the water are ordinarily based on the anticipated large future consumption, whereby a considerable deficit occurs during the first few years of operation, which must be met by general taxation in the case of municipal ownership of the works.   The gradual increase of revenue is, therefore, not a substantial gain, but merely an equalization of past outlays; and when the revenue becomes excessive, the time has clearly arrived for reducing the charges.

The pleas made in the discussion for sinking funds of long duration and for neglecting the depreciation of the plant are certainly strong, and cannot fail to strike a responsive chord in the minds of all who have had practical experience in the construction of costly works for comparatively small and poor communities.   If it were certain that there would be no great future growth of the city or town after the introduction of the works, these arguments would be perfectly valid; but with the rapid development of American cities, and the constantly increasing necessities for greater municipal expenditure in all directions, posterity will doubtless have ample burdens of its own without being loaded with the debts of the present generation.   Some recognition of this probability is, therefore, proper, and the question is to what extent should such be done in cases where no provision is

Mr. Kuichling. made by statutory law. Obviously there is here room for the exercise
of the most careful judgment.

Some instructive data have also been submitted in regard to the
ratios of the average daily consumption for the year to the maximum
consumptions per month, week, day and hour in a number of small,
medium and large cities. The thirteen cities and towns referred to by
Mr. Coffin are named in the following statement, which likewise
includes other pertinent data relating thereto derived from the
"Manual of American Water-Works," 1897, in order to give a some-
what clearer notion of the local conditions, and to this list there has
also been added the corresponding data relating to Detroit, taken
from the same source.

STATEMENT EXHIBITING GENERAL DATA RELATING TO THE CITIES AND
TOWNS MENTIONED IN THE DISCUSSION.

Name of city or town.	Population.	Average consumption per day.	Maximum consumption per day.	Number of taps.	Number of meters.	Miles of distributing pipes.
		Gallons.	Gallons.			
Wellesley, Mass.	3 600	175 000	240 000	685	656	26.0
Braintree, Mass.	4 848	....	....	490	....	14.0
Middleboro, Mass.	6 065	213 378	....	697	256	14.0
Attleboro, Mass.	7 577	306 357	564 000	....	638	28.6
Charlottetown, P. E. Island.	11 373	431 550	....	1 673	4	18.1
Brookline, Mass.	12 103	1 325 942	....	2 775	1 223	63.6
New London, Conn.	13 757	1 244 000	....	2 663	167	43.0
Marlboro, Mass.	13 805	510 000	620 000	2 209	844	36.0
Burlington, Vt.	14 590	888 083	1 000 000	2 969	1 261	36.0
Woonsocket, R. I.	20 830	621 464	1 058 092	1 847	1 590	41.0
Newton, Mass.	24 379	1 801 000	3 005 000	5 917	4 580	120.0
Taunton, Mass.	25 448	1 148 390	2 000 000	3 843	1 366	71.0
Yonkers, N. Y.	32 033	3 230 000	....	3 714	3 706	56.7
Detroit, Mich.	205 876	40 000 000	60 000 000	48 918	4 000	501.0

It may also be stated that the ratios of the average daily consump-
tion for the year to the maximum consumptions per month, week, day
and hour, which are given by Mr. Coffin, relate to Attleboro, Mass.,
for the year 1896, and are claimed to be substantiated by the records
of the Woonsocket, R. I., water-works.

In order to compare the aforesaid ratios relating to the two small
cities just mentioned, with the corresponding ratios pertaining to a
large city, the averages of the figures given by Mr. Williams for
Detroit for the three years, 1894, 1895 and 1896, have been reduced to
percentages and arranged with the others in the following table:

Mr. Kuichling.

NAME OF TOWN OR CITY.	RATIO OF AVERAGE RATE OF CONSUMPTION FOR ENTIRE YEAR TO THE MAXIMUM RATES FOR THE FOLLOWING PERIODS.			
	Month.	Week.	Day.	Hour.
	Per cent.	Per cent.	Per cent.	Per cent.
Attleboro, Mass., and Woonsocket, R. I., 1896....	122	134	155	333
Average for 13 small towns mentioned in preceding table, 1896..............................	123	....	....	....
Detroit, Mich., for 1894..............................	125	127	134	178
" " " 1895..............................	117	140	150	178
" " " 1896..............................	107	121	134	156
" " Average for 3 years..............	117	130	142	171

An examination of this table shows that in the smaller towns and cities, the variations in the rates of consumption are generally greater than in a large city, and that such is particularly noticeable in the case of the maximum hourly rate. This circumstance is readily attributable to the fact that a heavy draft made for fire or manufacturing purposes during a short period of time, in a small town where the entire daily consumption is moderate, induces a much larger ratio than occurs in a large city, where such drafts are distributed more uniformly throughout the day.

The figures given for the maximum hourly fire consumption in Detroit are also of interest, inasmuch as they confirm the author's estimate of the quantity of water or number of streams required for this purpose. Mr. Williams states that such consumption can fairly be taken at about 600 000 galls. per hour, the population in 1896 being about 280 000. The rate is therefore 10 000 galls. per minute, while from the author's formula (8) on page 16, the fire service would require a delivery of 11 700 galls. per minute on the assumption of 250 galls. per minute for each hose stream; but if an average of 225 galls. per minute for each hose stream is adopted, which is probably nearer to the truth, the formula will give a required delivery of 10 540 galls. per minute.

With reference to the loss by invisible leakage from the pipe joints and appurtenances of the distributing system, several interesting points have been brought out in the discussion. On the basis of tests made with a number of new pipe systems before the connection of service pipes thereto, Mr. Loweth considers that an allowance of from 60 to 80 galls. per inch-mile of pipe per day, or 600 to 800 galls. per mile of 10-inch pipe per day, is sufficient. While this quantity may be ample under the conditions stated, it is certainly too small after the system is several years old, and the lead joints have been strained by settlements and by repeated expansions and contractions of the pipes due to changes of temperature; also after the packing in the stuffing

Mr. Kuichling. boxes of stop-valves is partly decayed, the valves of fire hydrants damaged by use, and the tightness of the plugs in taps and curb cocks impaired by frequent handling or shock from water-ram in house pipes and mains.   All these elements must be taken into account after the work of construction is finished, and hence a much different standard is applicable to old pipe systems than to new contract work.

The same remarks also apply to the case of the instructive experiments made with comparatively new lines of pipe in Detroit; and it is fair to assume that if the same portions of the distributing system are again carefully tested after the lapse of some years, somewhat larger results will be found.   It is to be regretted that more experiments of this character are not available, as they afford valuable clues to many anomalies which are encountered in water-works practice.